Chapter 3. Microbiology

INTRODUCTION

The City of San Diego performs shoreline and water column bacterial monitoring in the region surrounding the South Bay Ocean Outfall (SBOO). The SBOO monitoring program is designed to assess general water quality, evaluate general patterns in movement and dispersal of the wastewater plume, and demonstrate a level of compliance with the 2001 California Ocean Plan (CSWRCB 2001) as required by the NPDES discharge permit. The final results of bacteriological and individual station compliance data are submitted to the International Boundary and Water Commission and San Diego Regional Water Quality Control Board in the form of monthly receiving waters monitoring reports. Overall bacteriological densities, together with oceanographic data (see Chapter 2), are evaluated to provide information about the movement and dispersion of wastewater discharged through the outfall. Analyses of these data may also implicate point or non-point sources other than the outfall as contributing to bacterial contamination events in the region. This chapter summarizes and interprets patterns in bacterial concentration data collected during 2005.

MATERIALS AND METHODS

Field Sampling

Water samples for bacteriological analyses were collected at fixed shore and offshore sampling sites during the year (**Figure 3.1**). Weekly sampling was performed at 11 shore stations to monitor bacteria levels along public beaches. Three shore stations (S0, S2, S3) located south of the US/Mexico border are not subject to 2001 California Ocean Plan (COP) water contact standards. Eight other shore stations (S4–S6, S8–S12) located within the United States between the border and Coronado are subject to the COP standards (see **Box 3.1**). In addition, 28 offshore stations were sampled monthly, usually over a 3-day period. However, this monthly sampling was not conducted in February pursuant to an agreement between the City and the Regional Water Quality Control Board (City of San Diego 2005b). These 28 offshore sites are located in a grid surrounding the outfall along the 9, 19, 28, 38, and 55-m depth contours. Three of these stations (I25, I26, I39) are considered kelp bed stations and are subject to the COP water contact standards. The kelp stations were sampled for bacterial analysis 5 times each month, such that each day of the week is represented over a 2-month period. The 3 kelp stations were selected because of their proximity to suitable substrates for the Imperial Beach kelp bed; however, this kelp bed is transient with variable size and density (North 1991, North et al. 1993). Thus,

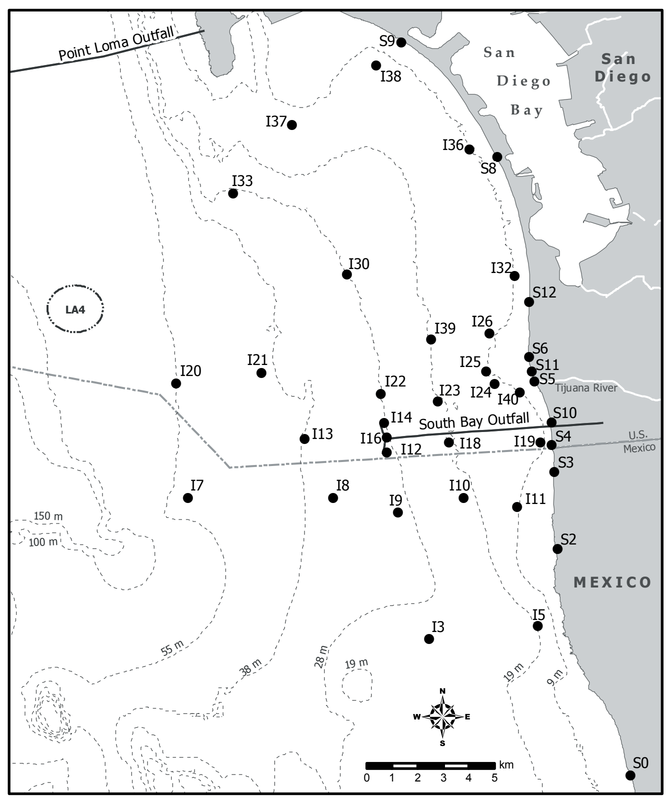

Figure 3.1
Water quality monitoring stations where bacteriological samples were collected, South Bay Ocean Outfall Monitoring Program.

Box 3.1

Bacteriological compliance standards for water contact areas, 2001 California Ocean Plan (CSWRCB 2001). CFU = colony forming units.

(1) *30-day total coliform standard* — no more than 20% of the samples at a given station in any 30-day period may exceed a concentration of 1000 CFU per 100 mL.

(2) *10,000 total coliform standard* — no single sample, when verified by a repeat sample collected within 48 hrs, may exceed a concentration of 10,000 CFU per 100 mL.

(3) *60-day fecal coliform standard* — no more than 10% of the samples at a given station in any 60-day period may exceed a concentration of 400 CFU per 100 mL.

(4) *geometric mean* — the geometric mean of the fecal coliform concentration at any given station in any 30-day period may not exceed 200 CFU per 100 mL, based on no fewer than five samples.

these 3 stations are located in an area where kelp is only occasionally found.

Seawater samples from the 11 shore stations were collected from the surf zone in sterile 250-mL bottles. In addition, visual observations of water color and clarity, surf height, human or animal activity, and weather conditions were recorded at the time of collection. The seawater samples were then transported on ice to the City's Marine Microbiology Laboratory and analyzed to determine concentrations of total coliform, fecal coliform, and enterococcus bacteria.

Offshore seawater samples were collected at 3 discrete depths and analyzed for total coliform, fecal coliform, and enterococcus bacteria, as well as total suspended solids, and oil and grease. These samples were collected using either a series of Van Dorn bottles or a rosette sampler fitted with Niskin bottles. Specific field sampling procedures are outlined in the City's Quality Assurance Plan (City of San Diego in prep). Aliquots for each analysis were drawn into appropriate sample containers. The samples were refrigerated on board ship and then transported to either the City's Marine Microbiology Laboratory for bacterial analyses or to the City's Wastewater Chemistry Laboratory for analysis of oil and grease, and suspended solids. Visual observations of weather and sea state were also recorded at the time of sampling.

Monitoring of the SBOO area and neighboring coastline also included aerial and satellite image analysis performed by Ocean Imaging Corporation (OI). All usable images captured during 2005 by the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite were downloaded, and several quality Landsat Thematic Mapper (TM) images were purchased. Aerial images were collected with OI's DMSC-MKII digital multispectral sensor (DMSC). Its 4 channels were configured to a specific wavelength (color) combination which, according to OI's previous research, maximizes the detection of the SBOO plume's turbidity signature by differentiating between the wastewater plume and coastal turbidity. The depth penetration of the imaging varies between 8 and 15 meters, depending on overall water clarity. The spatial resolution of the data is dependent upon aircraft altitude, but is typically maintained at 2 meters. Several aerial overflights were performed each month for a total of 11 flights from January through April and November through December and 6 flights from May through October.

Laboratory Analyses and Data Treatment

All bacterial analyses were performed within 8 hours of sample collection and conformed to the membrane filtration techniques outlined in the City's Quality Assurance Plan (City of San Diego in prep). The Marine Microbiology Laboratory follows guidelines issued by the EPA Water Quality Office, Water Hygiene Division and the California State Department of Health Services (CDHS) Environmental Laboratory Accreditation Program with respect to sampling and analytical procedures (Bordner et al. 1978, Greenberg et al. 1992).

Colony counting, calculation of results, data verification and reporting all follow guidelines established by the EPA (see Bordner et al. 1978). According to these guidelines, plates with bacterial counts above or below the ideal counting range were given greater than (>), less than (<), or estimated (e) qualifiers. However, these qualifiers were dropped and the counts treated as discrete values during the calculation of compliance with COP standards and mean values.

Shore and kelp bed station compliance with COP bacteriological standards were summarized according to the number of days that each station was out of compliance (see Box 3.1). Bacteriological data for offshore stations are not subject to COP standards, but were used to examine spatio-temporal patterns in the dispersion of the waste field. Spatial and temporal patterns in bacteriological contamination were determined from mean densities of total coliform, fecal coliform, and enterococcus bacteria. These data were calculated for each station by month, station, and depth. Monthly rainfall and climatological data (Lindbergh Field, San Diego, CA), oceanographic conditions (see Chapter 2), as well as other events (e.g., storm water flows, nearshore and surface water circulation patterns) identified through remote sensing data were evaluated relative to the bacterial data. COP and AB 411 (CDHS 2000) bacteriological benchmarks were used as reference points to distinguish elevated bacteriological values in receiving water samples discussed in this report. These were >1000 CFU/100 mL for total coliforms, >400 CFU/100 mL for fecal coliforms, and >104 CFU/100 mL for enterococcus bacteria. Furthermore, "contaminated" water samples were identified as samples containing total coliform concentrations ≥1000 CFU/mL and a fecal:total (F:T) ratio ≥0.1 (see CDHS 2000). Samples from offshore monthly water quality stations that met these criteria were used as indicators of the SBOO waste field.

Quality assurance tests were performed routinely on water samples to ensure that sampling variability did not exceed acceptable limits. Duplicate and split field samples were collected according to method requirements and processed by laboratory personnel to measure intra-sample and inter-analyst variability, respectively. Results of these procedures were reported in the Laboratory's Quality Assurance Report (City of San Diego 2006).

RESULTS AND DISCUSSION

Bacteriological densities in 2005 were generally high due to heavy rainfall from January and February (see Chapter 2). For example, annual mean concentrations of indicator bacteria along the shoreline (S5, S6, and S11) near the Tijuana River were similar to levels seen only during 1998 and 2004, 2 previous years with similarly heavy rainfall (**Figure 3.2**). Approximately 362 of the samples (18%) collected in 2005 had total coliform concentrations greater than or equal to the 1000 CFU/100 mL benchmark. Of these, 193 were collected at shore sites, 54 were collected at the kelp stations, and 114 were collected at the offshore sites. A total of 65 samples (11 kelp bed, 54 offshore) had F:T ratios ≥0.1 that indicated the presence of wastewater. These samples were further evaluated to assess possible patterns in plume movement.

Temporal Variability

January through March was the wettest period of the year and had the highest densities of indicator bacteria in shoreline samples (**Table 3.1**). Intermittent rainfall and continued stormwater discharges allowed high levels of indicator bacteria to persist through May. Most samples with total coliform concentrations exceeding 10,000 CFU/100 mL occurred during the wet months of January through May (n=112), compared to 7 instances during the remainder of the year. An unexpected increase in indicator bacteria at shore stations S0, S2, and S6 in August may be related to other non-point sources. Although there was no recorded rainfall in August, MODIS imagery

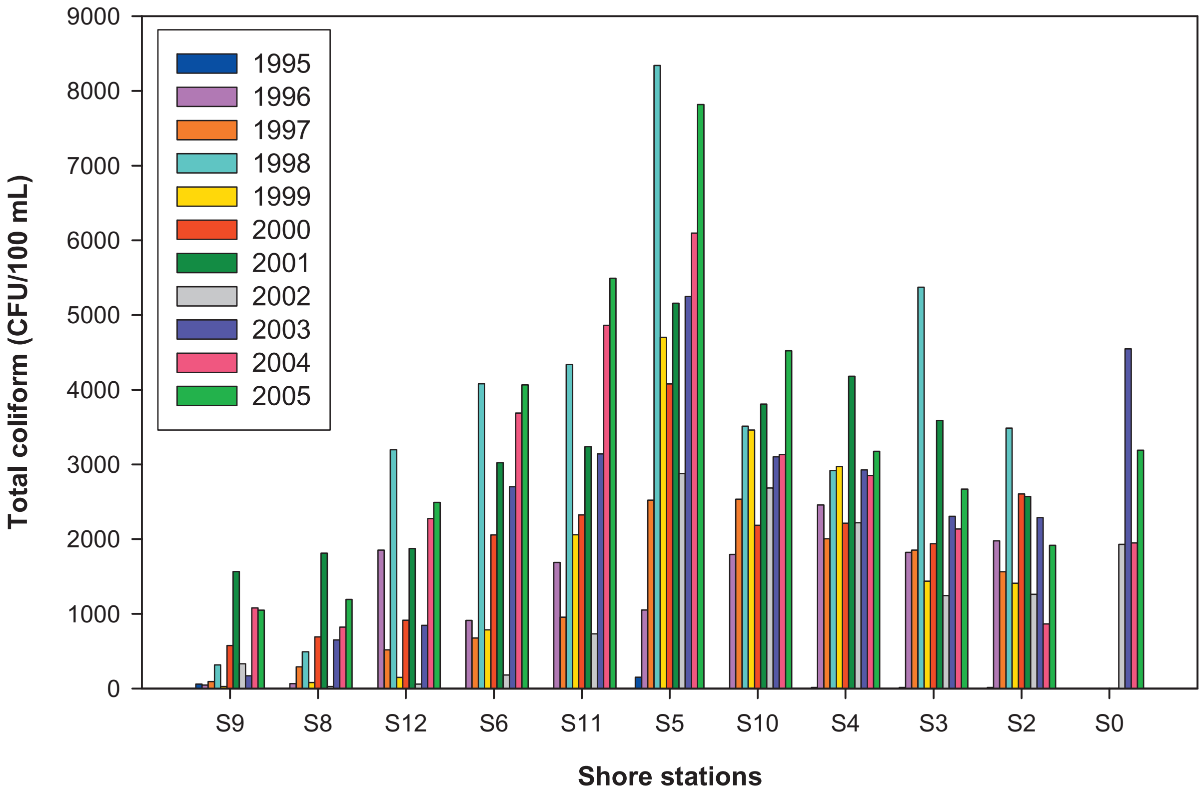

Figure 3.2
Mean annual total coliform densities for each SBOO shore station, 1995–2005. Stations are arranged from north to south on the x-axis. Stations S5, S6, and S11 are all within 1 km of the Tijuana River. Sampling for station S0 started in 2002.

taken on August 17 showed turbidity plumes from the Tijuana River and Los Buenos Creek, Mexico. Surface current data indicate a generally southern current regime through most of August (SDCOOS 2005), which may have driven materials from the Tijuana River southward. Bacteriological levels remained low at most of the shore stations from September to December, despite intermittent rains.

Similar to the shoreline results, the highest densities of indicator bacteria at the kelp bed stations occurred from January through March. Ninety-four percent of the samples with total coliform concentrations ≥1000 CFU/100 mL were collected from January through May (**Appendix A.1**). All of the samples collected in April and May had low fecal coliform densities and were probably not indicative of contaminated water from the outfall plume.

Monthly sampling at the offshore sites also showed distinct seasonal trends in indicator bacteria related to rainfall and storm discharge (**Figure 3.3**). Two-thirds of the 114 samples with total coliform concentrations ≥1000 CFU/100 mL occurred during January, March, April, and May (see **Appendices A.2, A.3**). Additionally, all but 2 of the 21 inshore (9 and 19-m contour) station samples representative of contaminated water occurred in January, March or April. Most, if not all, of these samples were likely related to discharge from the Tijuana River and Los Buenos Creek. During periods of northward current flows, discharge from the Tijuana River and Los Buenos Creek is carried up the coast towards Imperial Beach and may affect water quality at inshore stations (City of San Diego 2005a).

Seasonal trends related to water column stratification were also apparent in the offshore monthly water quality samples. The wastewater plume remained sub-surface most of the year, but was detected in surface waters at stations along the 28-m contour

Table 3.1

Shore station bacterial densities and rainfall data for the SBOO region during 2005. Mean total coliform, fecal coliform, and enterococcus bacteria densities are expressed as CFU/100 mL. Rainfall is expressed in inches as measured at Lindbergh Field, San Diego, CA. Sample size (n) for each station is given parenthetically and includes resamples.

Month (Rainfall)		S9 (54)	S8 (54)	S12 (57)	S6 (59)	S11 (63)	S5 (70)	S10 (59)	S4 (55)	S3 (52)	S2 (52)	S0 (52)
Jan	*Total*	3909	5388	9964	10057	11370	14857	4140	1010	8115	8059	8063
(4.49)	*Fecal*	176	441	394	1100	2220	9234	211	30	3610	2003	3504
	Entero	448	632	973	1669	2965	6460	46	117	3840	6010	4911
Feb	*Total*	6812	7004	7156	10709	12170	13300	8762	9200	6425	4720	3709
(5.83)	*Fecal*	686	1980	1496	4228	5030	9079	433	563	719	334	158
	Entero	687	2207	3173	4364	4670	7956	1154	748	1446	1189	565
Mar	*Total*	18	10	4270	6500	10068	16000	10373	8750	6002	4622	1356
(2.12)	*Fecal*	4	2	1062	3030	4371	8556	803	1810	392	141	88
	Entero	4	3	60	270	1357	9185	181	164	66	42	56
Apr	*Total*	12	56	3452	6620	11591	13791	12817	4581	2223	824	934
(0.59)	*Fecal*	18	6	240	3282	4583	7832	3867	410	184	73	61
	Entero	5	4	4	161	332	5823	141	9	16	4	11
May	*Total*	20	33	992	5527	6114	9085	5478	5515	3273	85	1388
(0.12)	*Fecal*	8	4	124	1742	3618	3255	2031	2031	2404	4	108
	Entero	27	4	3	173	1201	1635	63	99	87	6	11
Jun	*Total*	20	16	97	95	85	85	380	480	600	120	4070
(0.02)	*Fecal*	4	2	17	13	9	13	24	12	32	11	1060
	Entero	6	2	24	3	8	9	14	8	34	7	31
Jul	*Total*	200	74	110	256	155	110	155	515	156	1045	4525
(0.01)	*Fecal*	17	7	11	17	7	8	5	38	31	257	549
	Entero	26	44	7	9	12	15	10	36	24	112	214
Aug	*Total*	128	52	844	1564	1814	1257	460	694	208	3214	6904
(0.00)	*Fecal*	3	2	150	178	86	46	22	77	14	602	158
	Entero	6	3	17	48	21	20	9	8	6	130	67
Sep	*Total*	11	16	14	66	21	61	29	53	126	62	764
(0.10)	*Fecal*	4	3	6	19	5	7	9	6	25	4	92
	Entero	7	5	4	6	10	3	5	7	7	4	15
Oct	*Total*	41	11	205	90	40	67	103	408	4096	134	532
(0.46)	*Fecal*	16	2	16	12	13	6	11	30	226	25	14
	Entero	4	4	16	6	17	14	15	34	203	49	11
Nov	*Total*	9	4	3	39	10	15	2	8	862	8	1213
(0.16)	*Fecal*	5	3	2	2	2	4	3	2	54	3	159
	Entero	3	2	4	2	2	4	3	2	6	4	11
Dec	*Total*	16	11	9	9	37	10	12	7	16	45	5280
(0.25)	*Fecal*	8	3	2	3	2	6	2	2	3	6	171
	Entero	3	2	12	3	3	4	2	2	15	21	18
Annual Means												
	Total	**1047**	**1191**	**2490**	**4067**	**5494**	**7819**	**4523**	**3175**	**2668**	**1917**	**3189**
	Fecal	**86**	**227**	**334**	**1325**	**2097**	**4344**	**827**	**555**	**647**	**281**	**481**
	Entero	**112**	**268**	**394**	**678**	**1053**	**3641**	**152**	**112**	**445**	**586**	**458**

in January and June (**Figure 3.4**). Prior to the development of seasonal stratification that began in March, an unstratified water column allowed the wastewater plume to surface in January (see Chapter 2). CODAR surface current data indicate that an upwelling or water shearing event occurred in June and was the likely cause of the plume surfacing at station I22 on June 14.

Spatial Variability

Elevated bacterial densities along the shoreline and in shallow, nearshore waters appeared to be related to sources other than the SBOO. Proximity to the Tijuana River and Los Buenos Creek discharges influenced bacteriological levels along the shoreline (Table 3.1). The highest densities of indicator bacteria occurred at the shore stations closest to the Tijuana River (S4, S5, S6, S10, S11), where contaminants from upstream sources (e.g., sod farms and runoff not captured by the canyon collector system) and the estuary (e.g., decaying plant material) are released during increased river flow and extreme tidal exchanges (Largier et al. 2004). For example, station S5, located next to the Tijuana

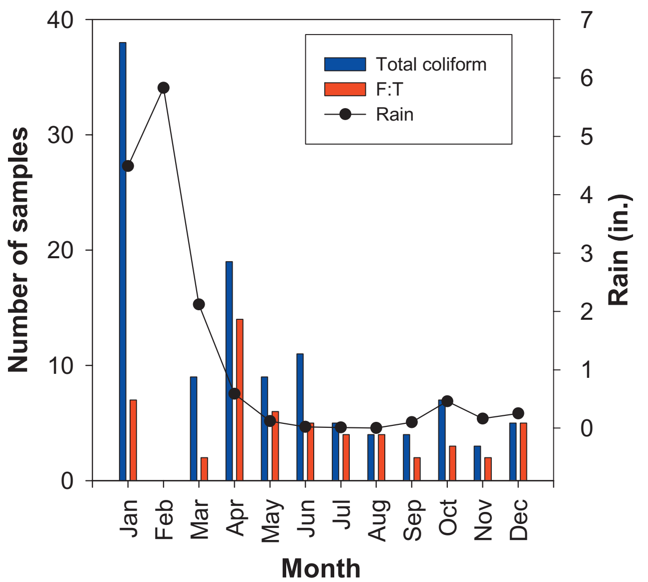

Figure 3.3
SBOO monthly water quality samples collected in 2005 with high bacteria densities. Total coliform=number of samples with total coliform densities ≥1000 CFU/100 mL; F:T=number of samples with total coliform densities ≥1000 CFU/100 mL and fecal to total coliform ratio (F:T) ≥ 0.1 (indicative of wastewater). Mean rainfall is measured at Lindbergh Field, San Diego, CA.

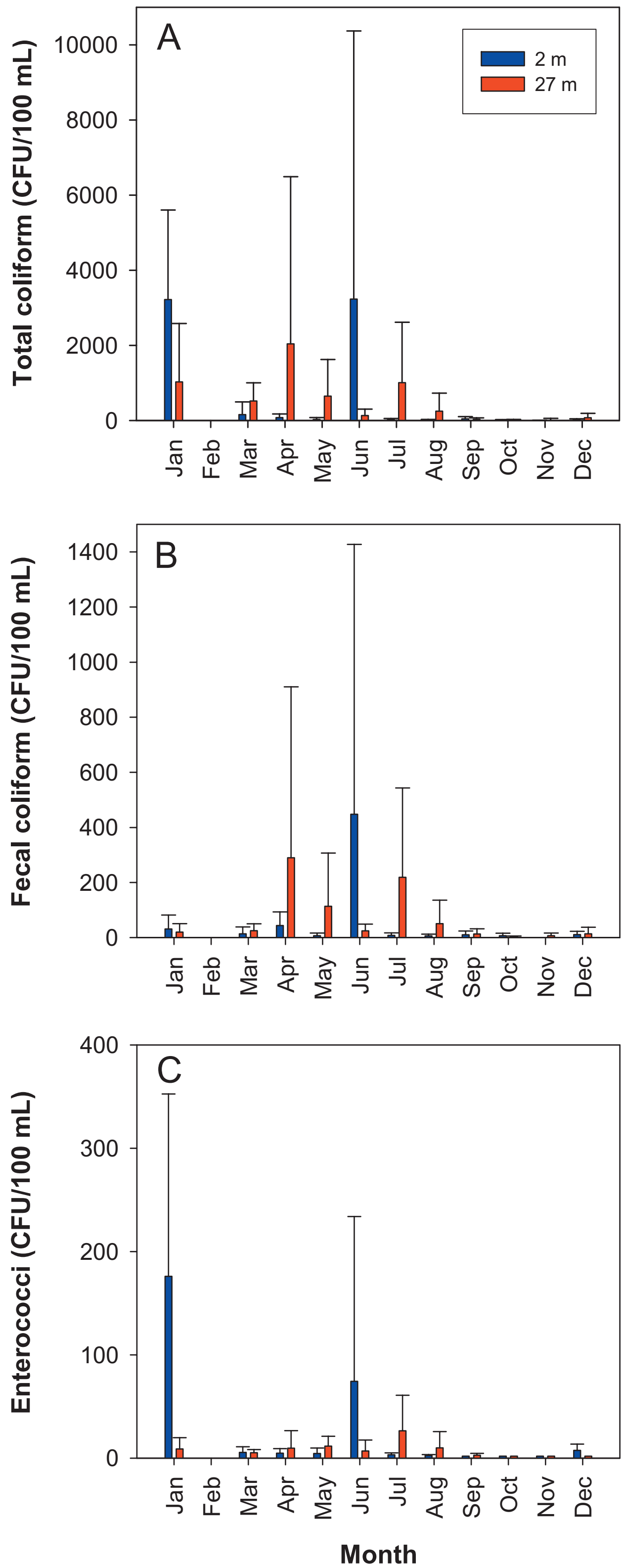

Figure 3.4
Bacteria concentrations at SBOO stations (I9, I12, I14, I16, and I22) along the 28-m contour for surface waters (2 m) and bottom waters (27 m) during 2005: (A) total coliform, (B) fecal coliform, and (C) enterococcus bacteria. Values are means±SD.

River mouth, had the highest bacteria levels of all of the shore stations sampled in 2005. Station S0, the southernmost shore station, was likely impacted by discharge from the nearby Los Buenos Creek and/or southerly alongshore flow carrying Tijuana River discharge. The 2 northern stations along the Coronado shore had the lowest overall bacteriological densities of all shore stations.

Discharge from the Tijuana River contained very high bacterial concentrations and affected water quality at the various nearshore stations (City of San Diego, unpublished data; Ocean Imaging 2005a, b). River discharge during January through May was likely responsible for the elevated bacterial densities in samples from inshore stations along the 9-m and 18-m contours. For example, there were 18 monthly inshore station water samples representative of stormwater (total coliforms ≥1000 CFU/100 mL and F:T ratios ≤0.1) taken in January (Appendix A.3). In addition, the samples from January with total coliforms ≥1000 CFU/100 mL and F:T ratios ≥0.1 came from inshore stations near the Tijuana River mouth, along the 9-m and 18-m contours (Appendix A.2).

Water samples considered indicative of the wastewater plume were detected most frequently at stations along the 28-m depth contour and from samples collected at depths ≥11 m (**Figure 3.5A**). Twenty-six of these samples occurred along the 28-m contour: 19 at the 3 outfall stations (I12, I14, I16), 6 at the northern stations I22 and I30, and 1 at the southern station I9. Six other samples were collected at deeper offshore stations (I8, I13, I20, I21) and 22 samples were collected at stations along the 9 and 19-m contours (I5, I10, I18, I19, I23, I24, I25, I39, I40).

There was limited bacteriological evidence that the wastewater plume reached surface waters in 2005. Only 9 of the 54 samples representative of contaminated water occurred in surface waters (2 m) (Figure 3.5B). These samples were collected in January (n=4), April (n=3), June (n=1), and October (n=1) (Appendix A.1). The January samples were collected from inshore stations after a 2-day storm dropped 1.7 inches of rain. The 3 April samples may have been affected by the Tijuana River turbidity plume, which was visible in MODIS imagery taken on April 6. Similarly, MODIS imagery taken on October 6 shows a turbidity plume emanating from Los Buenos Creek, Mexico that extended offshore to station I5. The San Antonio de los Buenos

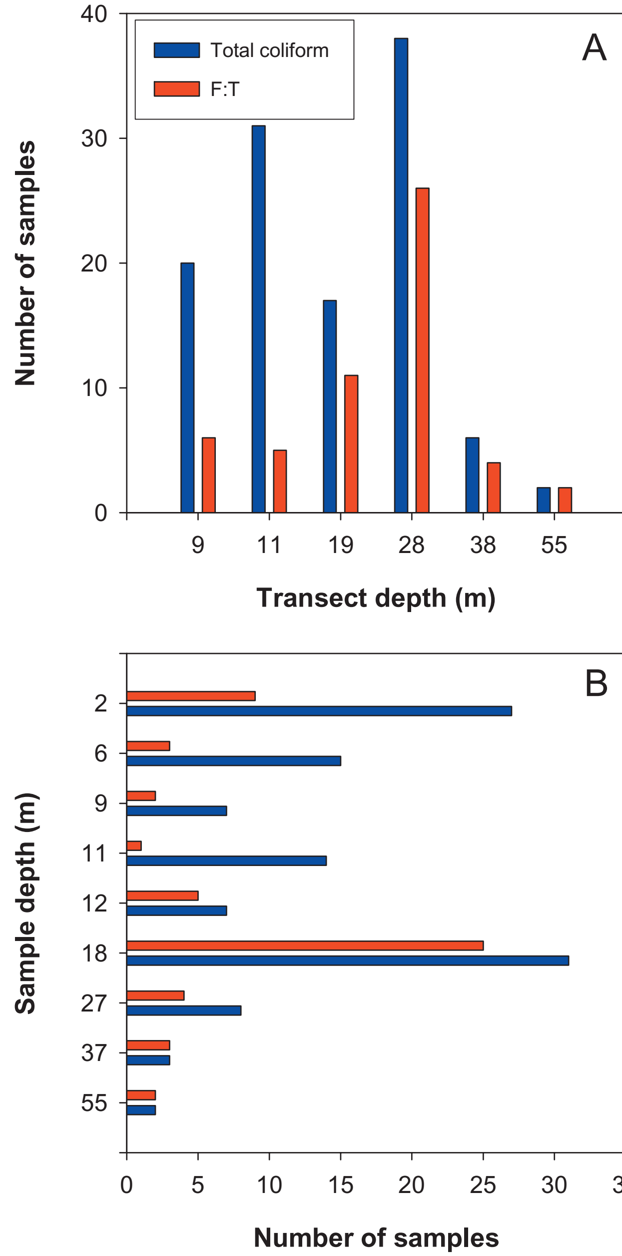

Figure 3.5
SBOO monthly water quality samples with high bacteria densities collected by (A) transect and (B) depth in 2005. Total coliform = number of samples with total coliform densities ≥1000 CFU/100 mL; F:T = number of samples with total coliform densities ≥1000 CFU/100 mL and fecal to total coliform ratio (F:T) ≥0.1 (indicative of wastewater).

Table 3.2

Summary of compliance with 2001 California Ocean Plan water contact standards for SBOO shore and kelp bed stations during 2005. Values reflect the number of days that each station exceeded the 30-day and 10,000 total coliform standards (see Box 3.1). Shore stations are listed north to south in order from left to right.

30-day Total Coliform Standard						**Shore stations**				**Kelp stations**		
Month	**# days**	**S9**	**S8**	**S12**	**S6**	**S11**	**S5**	**S10**	**S4**	**I25**	**I26**	**I39**
January	31	26	31	31	31	31	31	31	31	31	31	19
February	28	21	21	28	28	28	28	28	28	15	27	4
March	31	23	23	31	31	31	31	31	31	31	31	28
April	30	0	0	17	17	30	30	30	30	18	12	12
May	31	0	0	30	31	31	31	31	31	5	0	0
June	30	0	0	0	6	2	15	9	9	0	0	0
July	31	0	0	0	0	0	0	19	29	0	0	0
August	31	0	0	10	10	10	10	10	16	0	0	0
September	30	0	0	10	10	10	10	10	10	0	0	0
October	31	0	0	0	0	0	0	0	10	0	0	0
November	30	0	0	0	0	0	0	0	10	0	0	0
December	31	0	0	0	0	0	0	0	0	0	0	0
Percent Compliance		**81%**	**79%**	**57%**	**55%**	**53%**	**49%**	**45%**	**36%**	**73%**	**72%**	**83%**
10,000 Total Coliform Standard												
January	31	0	0	1	1	2	3	0	0	0	0	0
February	28	1	1	1	2	2	3	0	1	1	0	0
March	31	0	0	0	1	2	5	2	0	0	1	0
April	30	0	0	0	1	2	3	2	0	0	0	0
May	31	0	0	0	1	1	1	1	1	0	0	0
June	30	0	0	0	0	0	0	0	0	0	0	0
July	31	0	0	0	0	0	0	0	0	0	0	0
August	31	0	0	0	0	0	0	0	0	0	0	0
September	30	0	0	0	0	0	0	0	0	0	0	0
October	31	0	0	0	0	0	0	0	0	0	0	0
November	30	0	0	0	0	0	0	0	0	0	0	0
December	31	0	0	0	0	0	0	0	0	0	0	0
Total		**1**	**1**	**2**	**6**	**9**	**15**	**5**	**2**	**1**	**1**	**0**

Wastewater Treatment Plant releases its partially treated effluent through Los Buenos Creek (Ocean Imaging 2004) and this may have affected total and fecal coliform levels in the area. In contrast, samples indicative of wastewater were limited to waters 6 m and deeper during the rest of 2005.

Compliance with California Ocean Plan Standards – Shore and Kelp Bed Stations

Compliance with COP bacterial standards for U.S. shore and kelp bed stations in 2005 is summarized in **Tables 3.2** and **3.3**. As in the previous years, heavy rainfall caused some of the lowest compliance rates since 1999 when discharge began and compliance monitoring became required (see City of San Diego 2000–2005a). For example, compliance with the 30-day total coliform standard at the shore stations ranged from 36 to 81% in 2005 relative to 34 to 86% in 2004. However, the number of days that shore stations were out of compliance with the 10,000 total coliform standard increased from 31 in 2004 to 41 in 2005. The frequency of compliance with standards based on running means (i.e., the 30-day total, 60-day fecal, and geometric mean standards) was lowest during the rainy period of January through May.

Table 3.3

Summary of compliance with 2001 California Ocean Plan water contact standards for SBOO shore and kelp bed stations during 2005. Values reflect the number of days that each station exceeded the 60-day fecal coliform and geometric mean standards (see Box 3.1). Shore stations are listed north to south in order from left to right.

60-day Fecal Coliform Standard		**Shore stations**								**Kelp stations**		
Month	**# days**	**S9**	**S8**	**S12**	**S6**	**S11**	**S5**	**S10**	**S4**	**I25**	**I26**	**I39**
January	31	10	10	31	31	31	31	31	31	0	31	8
February	28	16	16	28	28	28	28	28	28	15	28	24
March	31	31	31	31	31	31	31	31	31	31	31	30
April	30	23	23	30	30	30	30	30	30	25	24	24
May	31	0	0	31	31	31	31	31	31	2	2	4
June	30	0	0	30	30	30	30	23	22	0	0	0
July	31	0	0	1	2	1	10	3	3	0	0	0
August	31	0	0	0	30	16	0	0	0	0	0	0
September	30	0	0	0	30	30	0	0	0	0	0	0
October	31	0	0	0	14	14	0	0	0	0	0	0
November	30	0	0	0	0	0	0	0	0	0	0	0
December	31	0	0	0	0	0	0	0	0	0	0	0
Percent Compliance		**78%**	**78%**	**50%**	**30%**	**34%**	**48%**	**52%**	**52%**	**80%**	**68%**	**75%**
Geometric Mean Standard												
January	31	0	0	22	28	10	31	0	0	0	0	0
February	28	0	0	0	6	14	28	0	0	0	0	0
March	31	0	0	9	28	31	31	14	7	0	0	0
April	30	0	0	0	3	30	30	26	18	0	0	0
May	31	0	0	0	26	26	31	18	0	0	0	0
June	30	0	0	0	0	0	1	0	0	0	0	0
July	31	0	0	0	0	0	0	0	0	0	0	0
August	31	0	0	0	0	0	0	0	0	0	0	0
September	30	0	0	0	0	0	0	0	0	0	0	0
October	31	0	0	0	0	0	0	0	0	0	0	0
November	30	0	0	0	0	0	0	0	0	0	0	0
December	31	0	0	0	0	0	0	0	0	0	0	0
Percent Compliance		**100%**	**100%**	**92%**	**75%**	**70%**	**58%**	**84%**	**93%**	**100%**	**100%**	**100%**

As in previous years, stations located near the Tijuana River mouth exceeded water quality standards more frequently than those farther northward. Only the 2 northernmost shore stations (S8 and S9) were compliant with COP standards ~80% of the time. In contrast, compliance at the more southern shore stations (S4, S5, S6, S10, S11, S12) was less than 60% for the 30-day total and 60-day fecal coliform standards. The proximity of these 6 stations to the Tijuana River may explain the frequency with which they were out of compliance. Excessive runoff volumes, tidal flushing, and frequent and persistent northward currents early in 2005 were probably responsible for the decreased compliance at stations north of the Tijuana River relative to previous years (City of San Diego 2005a, Ocean Imaging 2005a).

The 3 kelp stations were compliant with the COP standards over 68% of the time (Tables 3.2, 3.3). The lowest incidences of compliance occurred from January through April during periods of heavy rainfall. As with the shore stations, increased northward flow of surface waters in early 2005 affected compliance at stations northward of the Tijuana River (I26 and I39). Compliance with the 30-day total and 60-day fecal coliform standards ranged from 72% to 83% and 68% to 75%, respectively for these 2 sites. These values are similar to those reported in 2004. However, in years prior to 2004, the station farthest from shore (I39) was compliant with COP standards over 90% of the time. In general, it appears that shore and kelp station compliance with COP standards was affected most by shore-based discharges that increased during periods of record rainfall during the end of 2004 and early 2005.

Bacterial Patterns Compared to Other Wastewater Indicators

The monthly mean concentrations of oil and grease were <0.50 mg/L in 2005 (**Table 3.4**). Most individual samples had oil and grease concentrations of 0.20 mg/L throughout the year. The highest values (1.61–2.42 mg/L) occurred at 4 stations (I19, I23, I25, I26) in July, but the cause is uncertain. This level of oil and grease detection could indicate transport of the wastewater plume into nearshore surface waters, except that concentrations of indicator bacteria were low in these samples (<300 CFU/100 mL). Instead, July samples with high concentrations of bacteria indicative of the SBOO wastefield were found at depths of 12 m and below at stations I12, I16, and I23, suggesting a northeast transport below the thermocline.

Table 3.4
Means for total suspended solids (TSS; 3 depths) and oil and grease (O&G; 2 m depth) samples for each SBOO monthly water quality station during 2005. Ranges are given in parentheses. NS=not sampled (see text).

Month	O&G mg/L	TSS mg/L
January	0.20	9.2
	-	(0.2-57.0)
February	NS	NS
March	0.20	8.2
	-	(1.9-37.7)
April	0.20	6.3
	-	(0.2-27.7)
May	0.20	8.7
	-	(2.3-28.3)
June	0.20	7.8
	-	(2.1-38.5)
July	0.47	14.1
	(0.20-2.42)	(3.8-54.0)
August	0.20	10.7
	-	(1.7-32.8)
September	0.20	6.9
	-	(1.6-26.3)
October	0.20	4.4
	-	(1.6-10.4)
November	0.20	5.9
	-	(2.2-12.1)
December	0.20	4.1

Monthly mean concentrations of total suspended solids (TSS) ranged from 4.1 to 14.1 mg/L (Table 3.4). Individual values varied considerably, ranging between 0.2 and 57.0 mg/L, and did not correspond to bacterial concentrations. There were 194 TSS samples with concentrations ≥10.0 mg/L, but only 33 (17%) corresponded to samples where total coliform values were ≥1000 CFU/100 mL, and only 10 of these had F:T ratios ≥0.1. Instead, elevated TSS values corresponded primarily to stormwater discharges and plankton concentrations (see Chapter 2). The second highest TSS concentration was recorded in July during a red tide event at inshore station I25 (2 m sample). All corresponding bacteriological indicators were below 120 CFU/100 mL, while chlorophyll *a* was extremely elevated, dissolved oxygen values were relatively high, and transmissivity was low. Taken together, these results suggest a limited utility for high suspended solids or oil and grease concentrations as indicators of the waste field.

SUMMARY AND CONCLUSIONS

Record rainfall in 2005 strongly affected water quality conditions for the South Bay region. Bacterial concentrations in shore and kelp bed samples that exceeded COP standards appear to have been caused by contamination from river discharge and runoff during and after storm events. Bacterial concentration and visible satellite imagery data indicate that flows from the Tijuana River, Los Buenos Creek, and non-point source stormwater runoff are more likely to critically impact the water quality along the shore and at nearshore stations.

Data from the bacterial analyses for the South Bay region indicate that the wastewater plume from the SBOO rarely reached surface waters in 2005. Thermal stratification that began in March likely prevented the wastewater plume from surfacing through most of the year. Elevated bacterial counts evident near the surface in January, April, and October occurred during periods of heavy rainfall or when turbidity plumes from the Tijuana River or Los Buenos Creek reached the affected stations. Results indicative of wastewater reaching the surface occurred only in June. Remote sensing data suggests that frequent and persistent northward currents during the early part of 2005 affected the water quality at stations north of the Tijuana River. The majority of the subsurface (>2 m depth) monthly water quality samples indicative of the wastewater plume mostly occurred at depths of 18 m and below. These samples were collected predominantly near the outfall during the year.

In conclusion, although there were elevated bacterial densities detected at the nearshore and shore stations throughout the year, these data do not indicate a shoreward transport of the SBOO discharge plume. High amounts of rain, runoff from the Tijuana River and Los Buenos Creek, and northward currents appear to be the primary source of the nearshore bacteriological contamination. These conditions had the largest impact on water quality in the South Bay region during 2005.

LITERATURE CITED

Bordner, R., J. Winter and P. Scarpino (eds.). (1978). Microbiological Methods for Monitoring the Environment: Water and Wastes, EPA Research and Development, EPA-600/8-78-017. 337 pp.

City of San Diego. (2000). Annual Receiving Waters Monitoring Report for the South Bay Ocean Outfall, 1999. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2001). Annual Receiving Waters Monitoring Report for the South Bay Ocean Outfall, 2000. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2002). Annual Receiving Waters Monitoring Report for the South Bay Ocean Outfall, 2001. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2003). Annual Receiving Waters Monitoring Report for the South Bay Ocean Outfall, 2002. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2004). Annual Receiving Waters Monitoring Report for the South Bay Ocean Outfall (International Wastewater Treatment Plant), 2003. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2005a). Annual Receiving Waters Monitoring Report for the South Bay Ocean Outfall (International Wastewater Treatment Plant), 2004. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2005b). Letter to the Regional Water Quality Control Board, Region 9, dated February 8, 2005. Located at: San Diego Regional Water Quality Control Board offices, San Diego, CA.

City of San Diego. (2006). EMTS Division Laboratory Quality Assurance Report, 2005. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (in prep). EMTS Division Laboratory Quality Assurance Project Plan. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

[CDHS] California State Department of Health Services. (2000). Regulations for Public Beaches and Ocean Water-Contact Sports Areas. Appendix A: Assembly Bill 411, Statutes of 1997, Chapter 765. http://www.dhs.ca.gov/ps/ddwem/beaches/ab411_regulations.htm.

[CSWRCB] California State Water Resources Control Board. (2001). California Ocean Plan, Water Quality Control Plan, Ocean Waters of California. California Environmental Protection Agency, Sacramento, CA.

Greenberg A.E., L.S. Clesceri, and A.D. Eaton, eds. (1992). Standard Methods for the Examination of Water and Wastewater, 18th edition. American Public Health Association, American Water Works Association, and Water Pollution Control Federation. 1391 pp.

Largier, J., L. Rasmussen, M. Carter, and C. Scearce. (2004). Consent Decree – Phase One Study Final Report. Evaluation of the South Bay International Wastewater Treatment Plant Receiving Water Quality Monitoring Program to Determine Its Ability to Identify Source(s) of Recorded Bacterial Exceedances. Scripps Institution of Oceanography, University of California, San Diego, CA. 241 pp.

North, W.J. (1991). The Kelp Beds of San Diego and Orange Counties. Wheeler J. North. 270 pp.

North, W.J., D.E. James, and L.G. Jones. (1993). History of kelp beds (*Macrocystis*) in Orange and San Diego Counties, California. Hydrobiologia, 260/261: 277–283.

Ocean Imaging. (2004). Satellite and Aerial Coastal Water Quality Monitoring in The San Diego/Tijuana Region: Two-Year Summary Report. Solana Beach, CA.

Ocean Imaging. (2005a). Satellite and Aerial Coastal Water Quality Monitoring in The San Diego/Tijuana Region: Monthly Report for: January, February, and March 2005. Solana Beach, CA.

Ocean Imaging. (2005b). Satellite and Aerial Coastal Water Quality Monitoring in The San Diego/Tijuana Region: Monthly Report for: April through September 2005. Solana Beach, CA.

SDCOOS. (2005). San Diego Coastal Ocean Observing System. San Diego, CA. http://www.sdcoos.ucsd.edu/.